THE MORPHOLOGY AND GERMINATION OF THE SEED OF ELEPHANTORRHIZA ELEPHANTINA

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THE GENUS *Elephantorrhiza* Benth., described in 1842, belongs to the family Mimosaceae and consists, according to Phillips (1922, 1951), of only seven species with *Elephantorrhiza elephantina* (Burch.) S. Keels, the well known "elandsboontjie," as the type species. All the representatives of the genus are small shrubs that vary in height from about one foot, as in *E. elephantina*, to small trees of ten feet and higher in *E. burkei* Benth.

These plants are interesting in that they have thickened underground bases. It is a feature that generally occurs and is known in the Monocotyledoneae, but which is probably relatively rare in the Dicotyledoneae. However, this characteristic occurs in more South African Dicotyledoneae than is generally realized. Neither is it limited to a single or a few families, but it is found in a variety of families. The genera *Talinum* (Portulacaceae), *Gyrocarpus* (Hernandiaceae), *Elephantorrhiza* (Mimosaceae), *Bauhinia* (Caesalpinaceae), *Neorautanenia*, *Dolichos*, *Mucuna*, and *Erythrina* (Papilionaceae), *Rhoicissus* and *Cissus* (Vitaceae), *Adenia* (Passifloraceae), *Begonia* (Begoniaceae), *Cussonia* (Araliaceae), *Adenium* and *Pachypodium* (Apocynaceae), *Raphionacme* and *Ceropegia* (Asclepiadaceae), *Ipomoea* (Convolvulaceae), *Pterodiscus*, *Harpagophytum*, and *Sesamothamnus* (Pedaliaceae), and *Coccinia* (Curcurbitaceae) are particularly important in this respect.

Knowledge of the morphological character and development of these thickened bases is to a large extent still only speculative, while little is known of the morphology and germination of the seed. The aim of this study is an attempt to gain a better insight into the morphology and germination of the seed and the establishment of the seedling, the latter being very interesting and unusual for the Dicotyledoneae.

MATERIAL AND METHODS

The plant which we studied, *Elephantorrhiza elephantina*, is a small shrub up to 2 feet high (FIGURE 1) of which the underground parts are perennial while the stems above the ground partially or wholly die down annually during winter.

The leaves are bipinnately compound and the inflorescence consists of

* Most of this work was done while the senior author was a Mercer Research Fellow at the Arnold Arboretum, Harvard University, and was supported by a grant from the C.S.I.R., Republic of South Africa.

FIGURE 1. Single *Elephantorrhiza elephantina* plant to show bipinnately compound leaves and inflorescence.

small cream-colored flowers in a spike-like cluster that is up to 3 inches long. Although the ripe fruit is fairly hard, it readily absorbs water and disintegrates completely when wet, as a result of the softening of the pericarp flaps that break away from the remaining seams. It has been observed in the veld, that a large percentage of the seeds germinate on the surface of the soil within these moist, disintegrating fruits. At this stage it is not yet clear whether this is the ideal condition for the germination of the seeds.

The fleshy underground parts are very rich in tannic acid, a substance which is not only of medicinal value, but is also used in the tanning of hides. According to MacOwen (1897) an extract of the fleshy parts is used to treat sunburn, while Bryant (1909) maintains that the core of the "root" is used by Zulus as a cure for dysentery and diarrhoea. Thonner (1915) states that it is used as a fish poison and as a medicine, while it is known that an extract of the fleshy "roots" is an effective remedy for haemorrhoids.

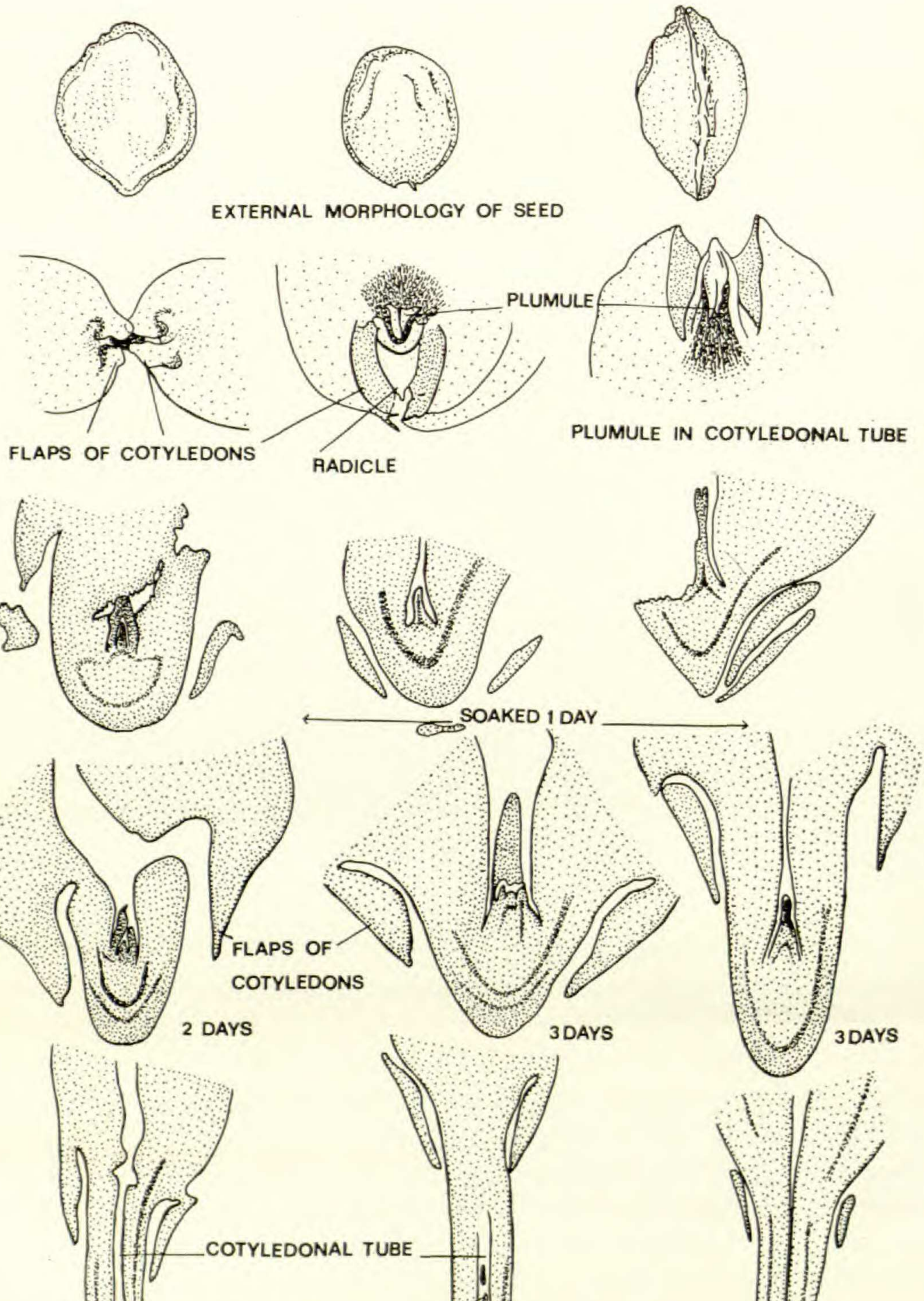
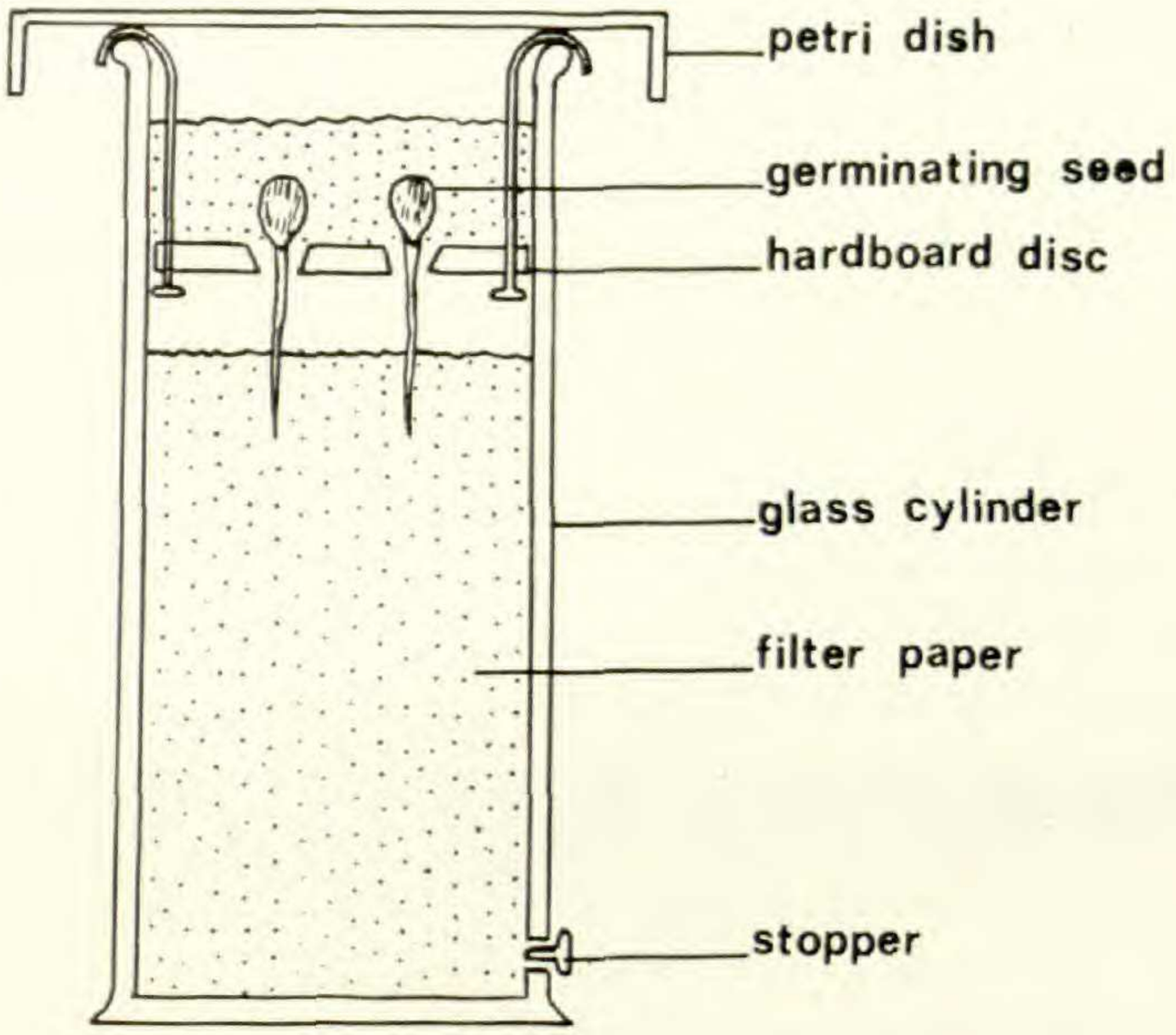


FIGURE 2. Drawings to illustrate seed morphology and the elongation of the cotyledon (petiole) tube during germination.

Steyn (1949) is not in agreement with Burtt-Davy that the plant is not toxic and is of the opinion that the seed contains an irritant toxin, which is harmful to animals.

Elephantorrhiza elephantina occurs fairly generally in the Eastern Cape Province, the Orange Free State, Natal, Transvaal, South West Africa,



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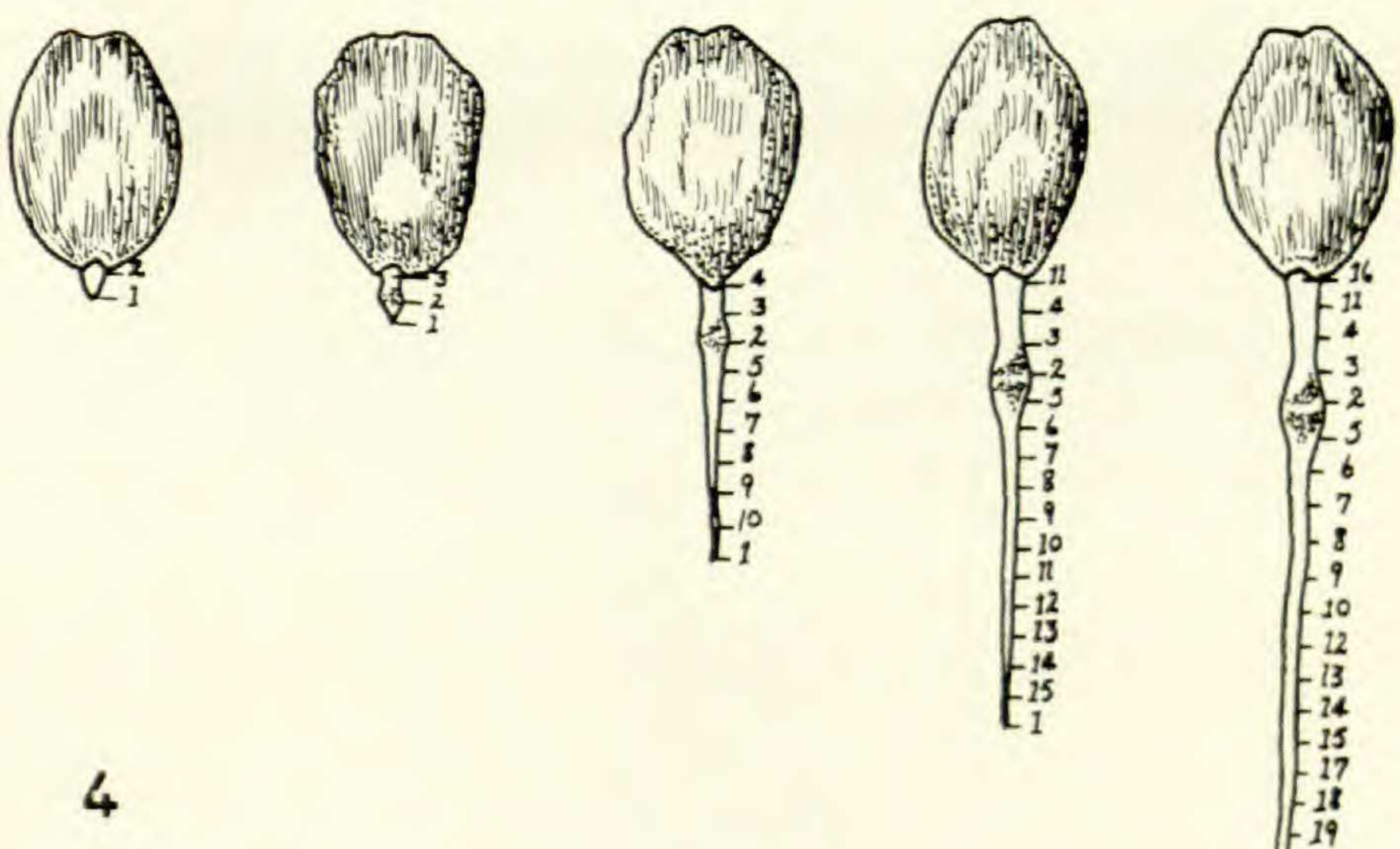

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FIGURES 3 AND 4. FIG. 3. Apparatus used to investigate the mode of germination of the seeds. FIG. 4. Diagrammatic representation of the elongation of the cotyledon (petiole) tube and "taproot" during germination.

Rhodesia, and Portuguese East Africa. In parts of the Transvaal highveld during spring it is often very common in veld which has been burned.

The seeds used in this investigation were collected in the vicinity of Pretoria, where the plant occurs fairly frequently in grassveld.

For the study of the morphology of the seed, dry seeds as well as seeds that had been soaked overnight were used. After drawings of the different seed forms were made (FIGURE 2) the hard leathery testa was carefully removed in order to study and to make drawings of the embryo, which is very brittle when dry.

Most of the material used for microtome sections was prepared according to standard methods and cast in wax. In some instances the material was fixed in acrolin, treated according to the method of Feder (unpubl.) and embedded in methacrylate resin. Although the latter method is more effective for the preparation of very thin sections, it is disadvantageous in that no serial sections can be made.

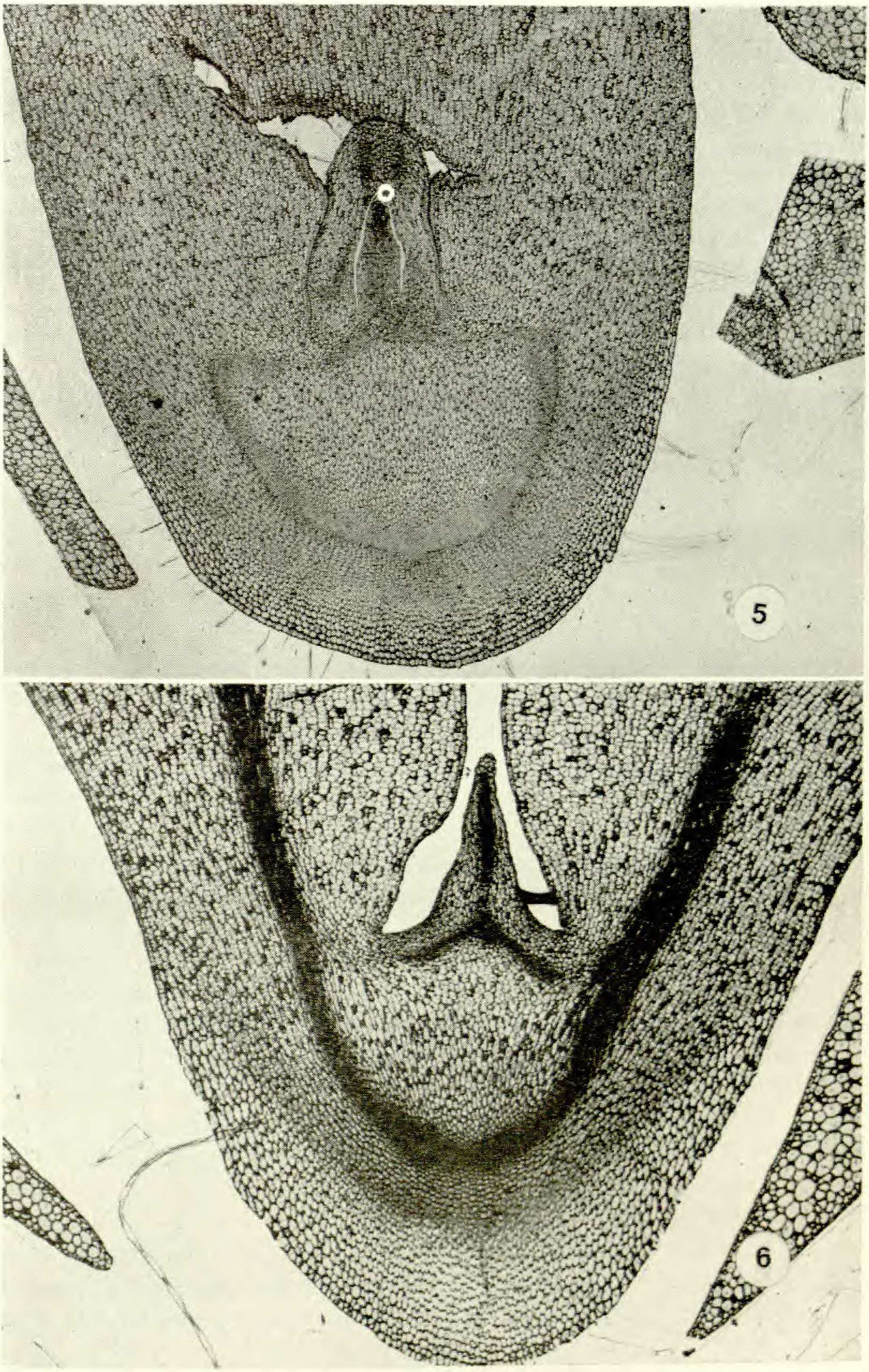
The seeds used in the germination tests and for the study of the seedlings were first wounded with a small knife to make an opening in the testa for moisture to penetrate the seed. They were then soaked overnight, after which they were placed on wet filter paper in petri dishes and left to germinate at a room temperature of about 25° C. In cases where the development of the seedling was followed, the seed was germinated in pure vermiculite in glazed pots about 18 inches high. The young seedlings, of which specimens were removed daily to be studied, fixed, and to be used in the making of drawings, were easily washed out of the vermiculite by means of a slow stream of water.

To trace the locality of elongation of the seedlings, germinated seeds were placed in holes made in a hardboard disc, which fitted into a glass cylinder impermeable to light. This was filled with moist crumpled filter paper and care was taken throughout to ensure that the roots did not come into contact with it (FIGURE 3).

The pattern of elongation of the axis of the seedling was traced by means of Indian ink markings, 1 mm. apart on the developing seedlings (Miller & Wetmore, 1945). The first mark was made on the tip of the radicle immediately after its appearance at the micropyle. Thereafter, serial marks were made on the elongating seedling axis and schematic and numerical drawings were made on a piece of paper. Where serial marks moved farther apart, new marks were made in between to show the precise region of elongation (FIGURE 4).

RESULTS

Morphology of the seed. The seeds of *Elephantorrhiza elephantina* (FIGURE 2) exhibit a wide variation in regard to size and form. However, the majority of the seeds are spherically flattened, being slightly tapered in the region of the micropyle. Some of the seeds are also tapered on the side opposite the micropyle. If the seeds are densely packed to-



FIGURES 5 and 6. FIG. 5. Longitudinal section through the base of embryo to show the position of the radicle and plumule. FIG. 6. Longitudinal section through base of seed during initial stages of germination to show the plumule in the still very short cotyledon (petiole) tube.

gether in the pods, they are flattened laterally. The seeds which are relatively large are up to 2 cm. broad and 2.5 cm. long.

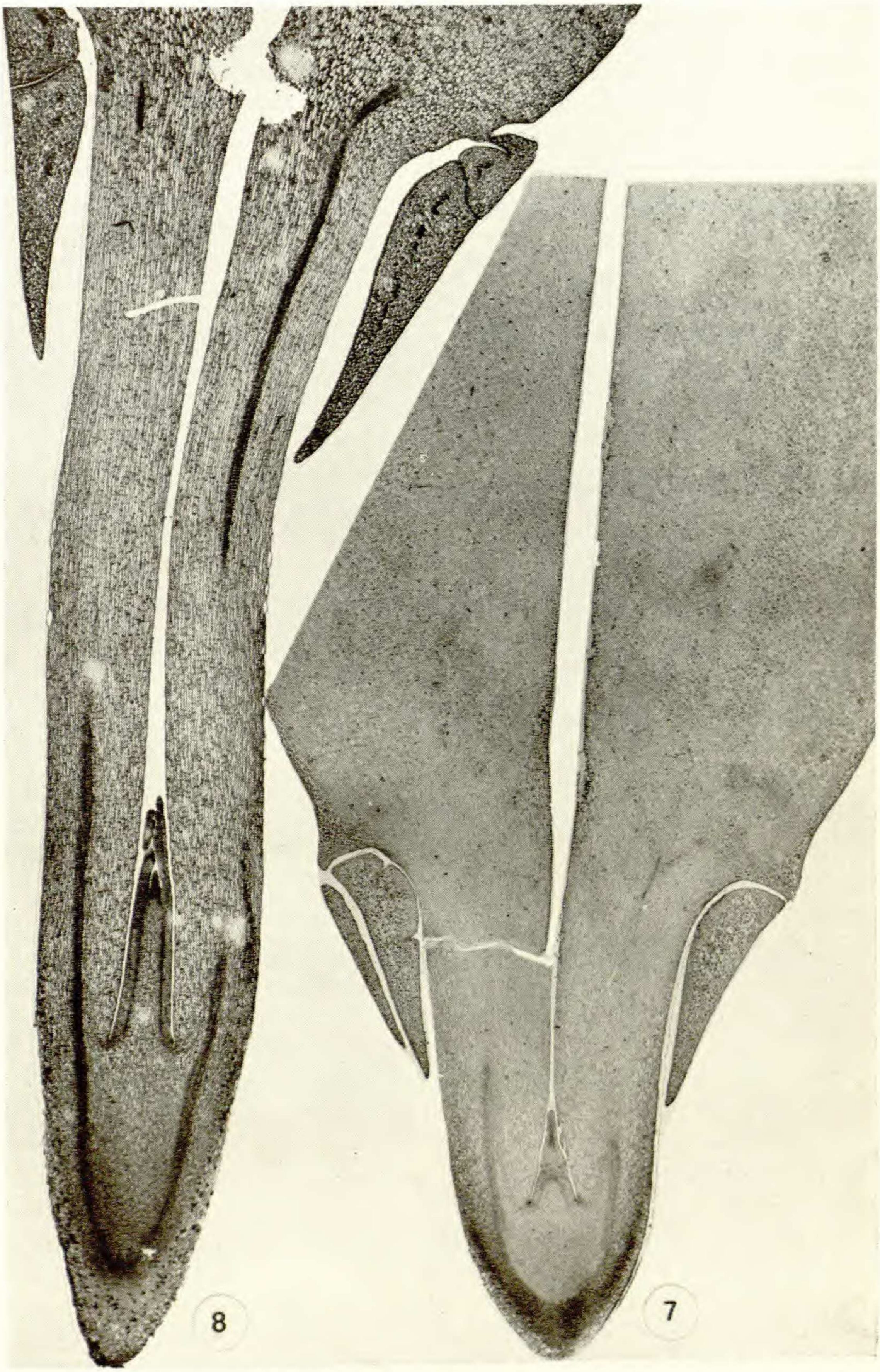
The embryo is surrounded by a hard leathery testa and the two thick and fleshy cotyledons are very brittle and are easily broken in the dry condition. They lie close together to protect the radicle and plumule between them. The cotyledons are oval in outline and asymmetrical at the base. Each cotyledon has two flaps at its base that fold over one another and protect the relatively large radicle (FIGURE 2). The cotyledons have short petioles which are fused to form a cotyledon tube or cylinder which surrounds the plumule and protects it (FIGURES 5–10). In the fusion area between the cotyledon tube and hypocotyl there are indications of meristematic tissue (intercalary meristem) which, together with cell elongation, is responsible for the elongation of the cotyledon tube during germination (FIGURES 6–8).

Germination of the seed. During the epigeal germination which usually occurs while the seed lies on the surface of the soil, the cotyledon flaps move apart and the radicle is forced out through the micropyle. According to the results obtained from the seedlings marked with Indian ink, it is clear that it is initially the cotyledon tube which elongates to carry the radicle out and that the apical growth of the radical only begins one or two days after germination has started (FIGURE 4). Root growth is fairly rapid and after one week tap roots of up to 9 inches in length were recorded.

Longitudinal sections of the embryo confirmed without question that the cotyledon tube elongates not only to carry the radicle out, but also to implant the plumule into the ground (FIGURES 6–8). These sections also clearly show the meristematic zone as well as the cylindrical form of the cotyledon tube. In cross section it can be seen that the tube in the earlier stages of germination is flattened (FIGURE 9) but later becomes cylindrical as can be seen in FIGURE 10. Under favorable conditions this cotyledon tube may be up to 4 cm. long, which is probably of particular ecological importance as it apparently ensures that the seedling becomes established deeply enough.

The plumule at first develops more slowly than the radicle. Between two to three weeks elapse from the time the radicle appears until the plumule becomes visible. It breaks through the cotyledon tube at the point of fusion between the cotyledon tube and the hypocotyl (FIGURE 11). At this stage the "root" has already undergone considerable secondary thickening and has formed a conspicuous loose periderm which peels off in brown flakes (FIGURE 13). The first sign of secondary thickening of the "root" (hypocotyl) is already visible three days after the radicle makes its appearance. No lateral roots were found on the upper and thickest part of the "root," while many lateral roots were present lower down (FIGURE 13).

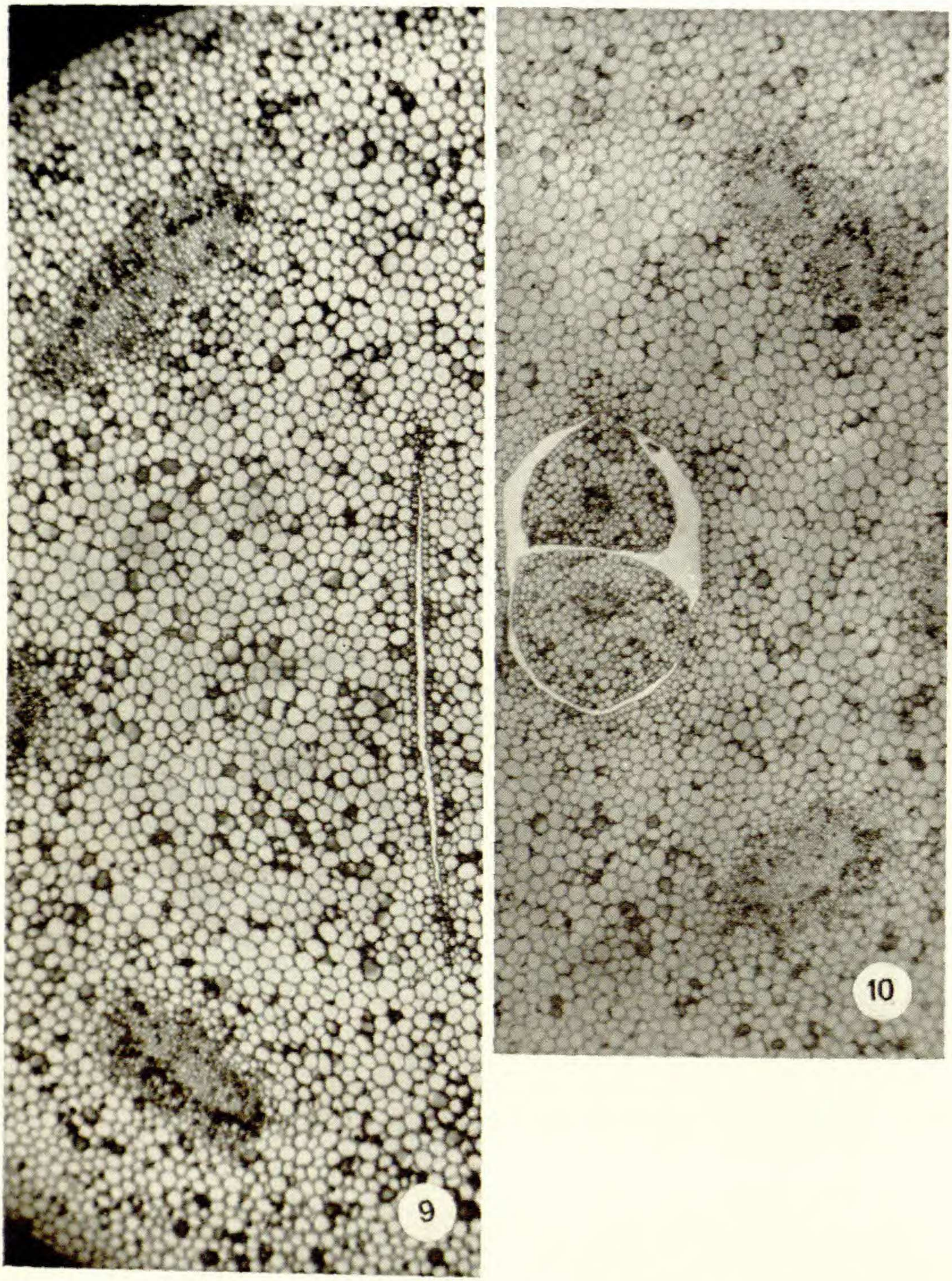
Each cotyledon stalk has three collateral vascular bundles (FIGURE 11). It is interesting to note that these bundles in the petioles of the cotyledons undergo secondary thickening, and also form a periderm (FIGURE 12).



FIGURES 7 and 8. FIG. 7. Longitudinal section through embryo to illustrate elongation of petiole tube. FIG. 8. Longitudinal section of petiole tube of about 2 cm. length.

DISCUSSION

The type of germination encountered in *Elephantorrhiza elephantina* is not only very interesting, but also extraordinary for a representative of the Dicotyledoneae. It is the characteristic type of germination of representatives of the Monocotyledoneae, of which species of the South



FIGURES 9 and 10. FIG. 9. Transverse section through petiole tube to illustrate the three vascular bundles of each petiole and the flattened petiole cavity. FIG. 10. Transverse section through cylindrical petiole tube with young stem and leaf.

African genera *Phoenix*, *Jubaea*, and *Hyphaene* are probably the most important and most conspicuous. In these genera the radicle and plumule, as in the case of *Elephantorrhiza elephantina*, are also carried out by a cotyledon tube and down into the ground, the plumule bursting through the cotyledon tube some time after the radicle has made its appearance through the micropyle. The germination of the seed of *Elephantorrhiza elephantina* is also interesting in that the cotyledons remain within the testa, a feature which not only agrees with what is found in the Monocotyledoneae, but which is also characteristic of certain representatives of the order Policarpicae (Ranales) such as *Jeffersonia diphylla* (Berberidaceae), *Ranunculus* spp., and *Eranthis* spp. (Ranunculaceae) (Wettstein, 1962). In these Dicotyledoneae which exhibit some relationships with certain Monocotyledoneae, the radicle and plumule are also carried out by the elongating cotyledon stalks.

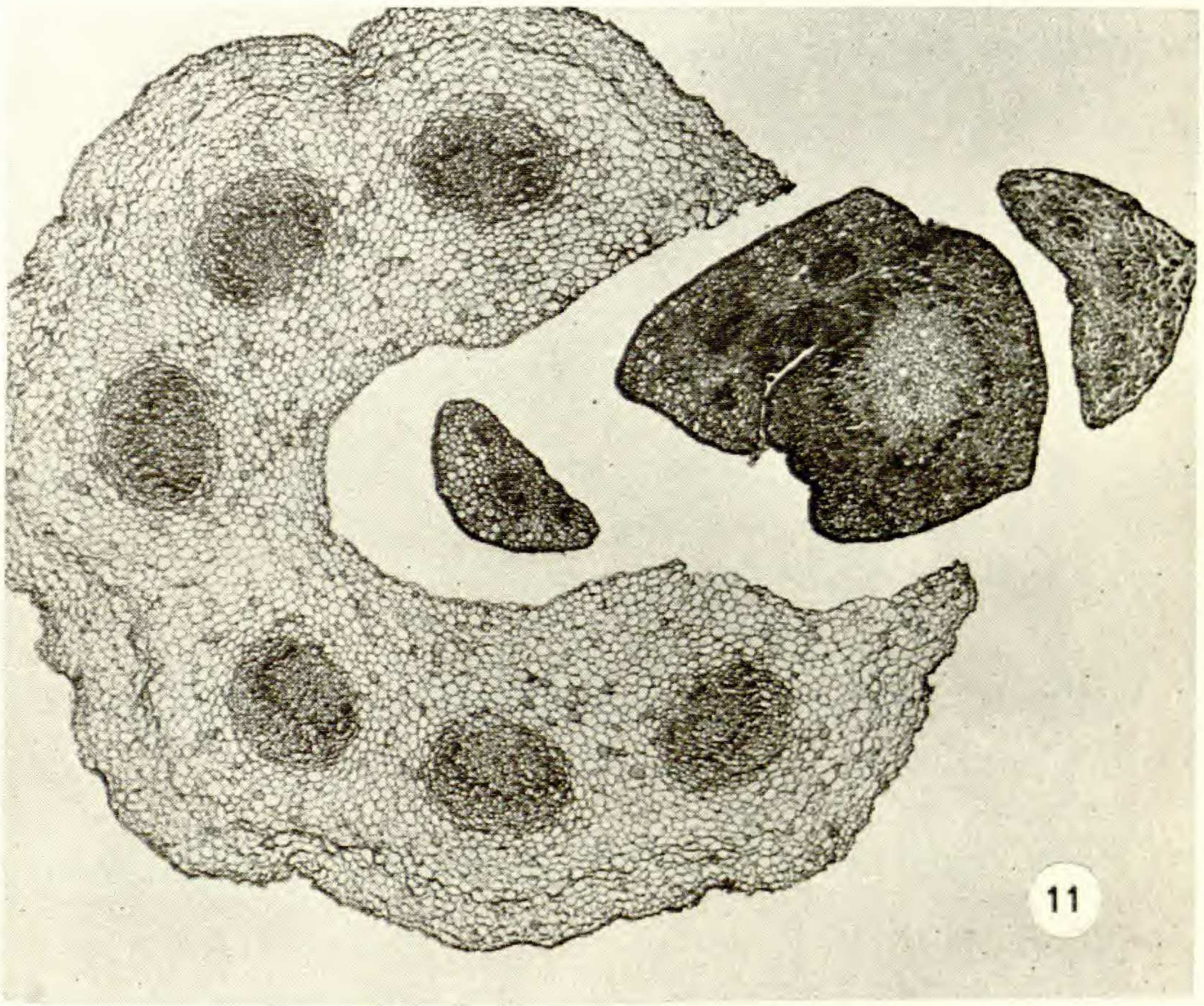


FIGURE 11. Transverse section through petiole tube and young plumule at the stage when the plumule breaks through the tube.

The same type of germination is also observed in *Elephantorrhiza burkei*, and according to Hofmeyr (1921–22) it is encountered in a representative of the Cucurbitaceae. Asa Gray (Hofmeyr, 1921–22), in his *Structural Botany*, maintains that it occurs in the American species *Megarrhiza californica* of the Cucurbitaceae.

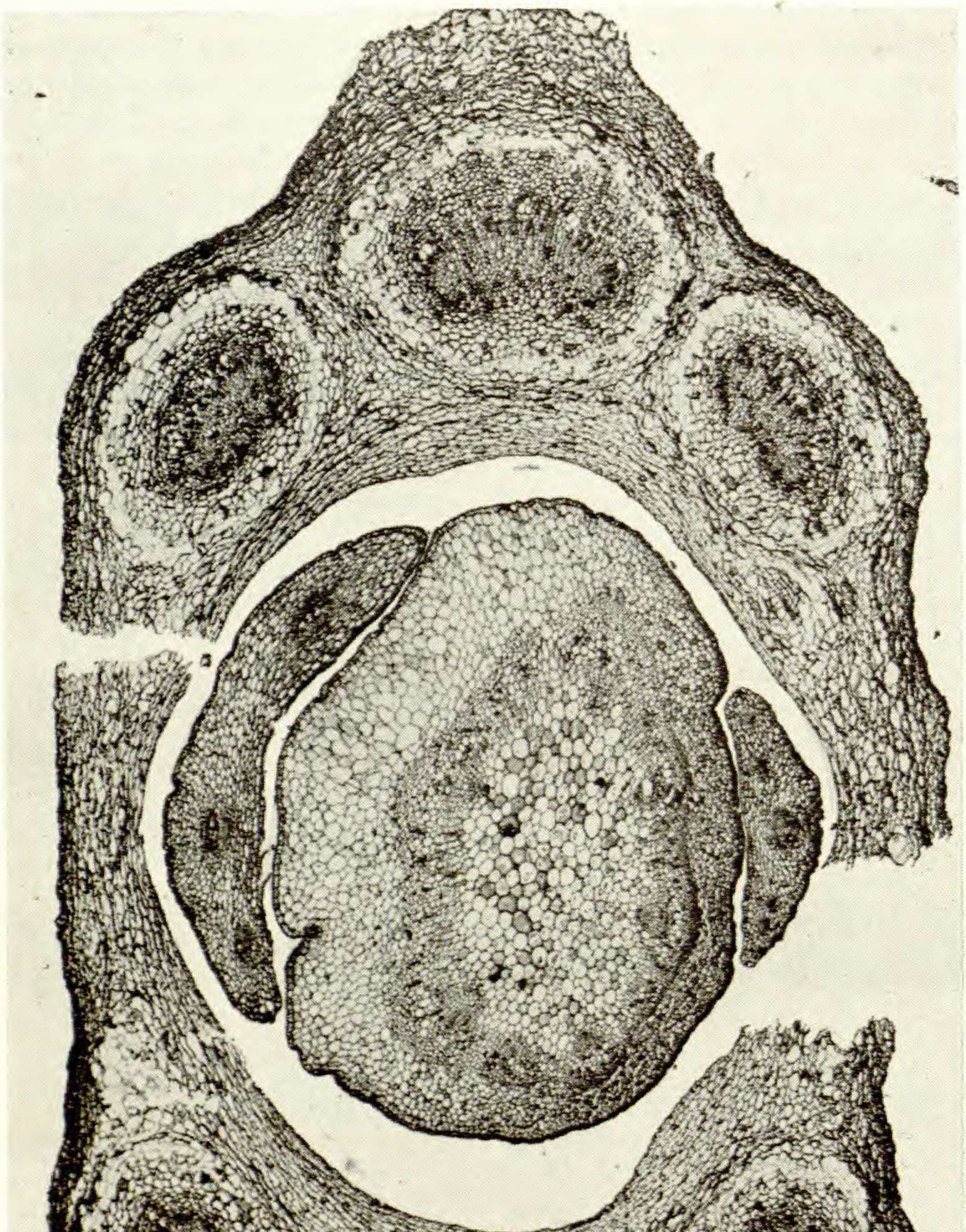


FIGURE 12. Transverse section through petiole tube and young stem to illustrate secondary thickening of the petiolar collateral vascular bundles.

Whether the germination of the seed and the development of the seedling of *Elephantorrhiza elephantina* is of any phylogenetic value is not clear. The phylogenetic importance of the germination morphology in the Polycarpicae can hardly be disputed, but here it appears as though it could be a case of convergence. Nevertheless, the facts that have been brought to light are most interesting and it can only be determined through further research how many of the South African plants exhibit this type of germination and whether it is of any phylogenetic significance.

SUMMARY

Elephantorrhiza elephantina the well known "elandsboontjie" of the family Mimosaceae is a small shrub of which the underground bases are thickened and fleshy.

The germination of the seed of this species is interesting in that the radicle and plumule are carried out by the cotyledon petioles which elongate and which are fused to form a cotyledon tube. This cotyledon tube can be up to 4 cm. long and probably contributes to the successful establishment of the seedling.

The elongation of the cotyledon tube is the result of cell elongation, and probably an intercalary meristem which is situated at the base of the cotyledons.

The tap root develops very rapidly, while the main stem breaks through the cotyledon tube about two weeks after the radicle has made its appearance.

Although this type of germination is characteristic of certain Monocotyledoneae and the cotyledon petiole of certain of the representatives of the Polycarpicae also elongate during germination, evidence is as yet incomplete to evaluate the phylogenetic importance thereof. As far as our present knowledge goes it appears as though it may be a case of convergence.

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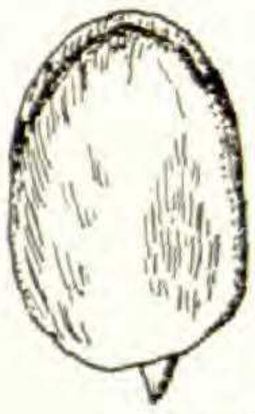
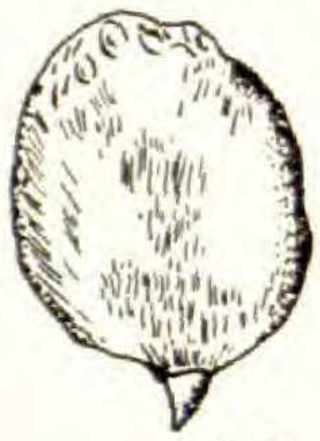
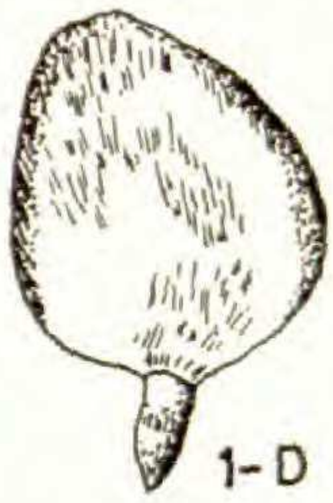
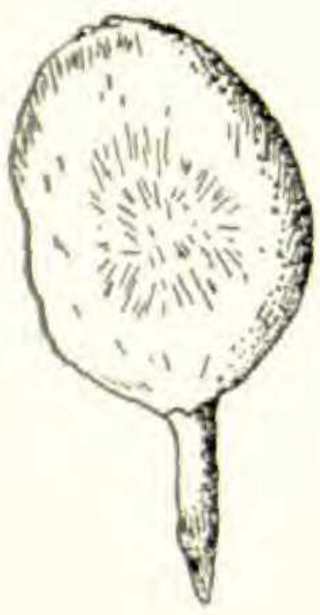
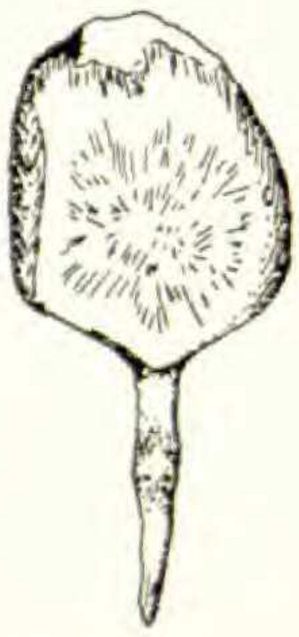










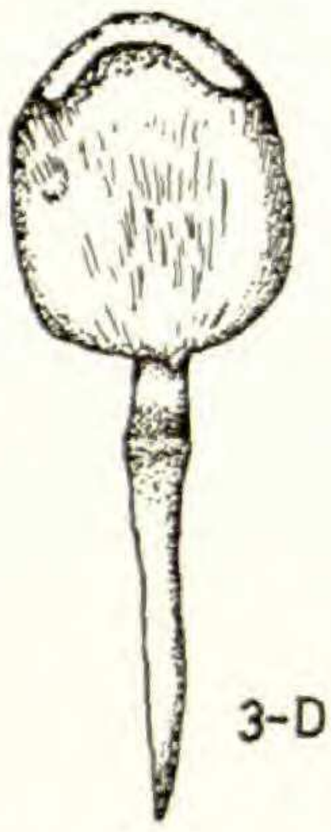
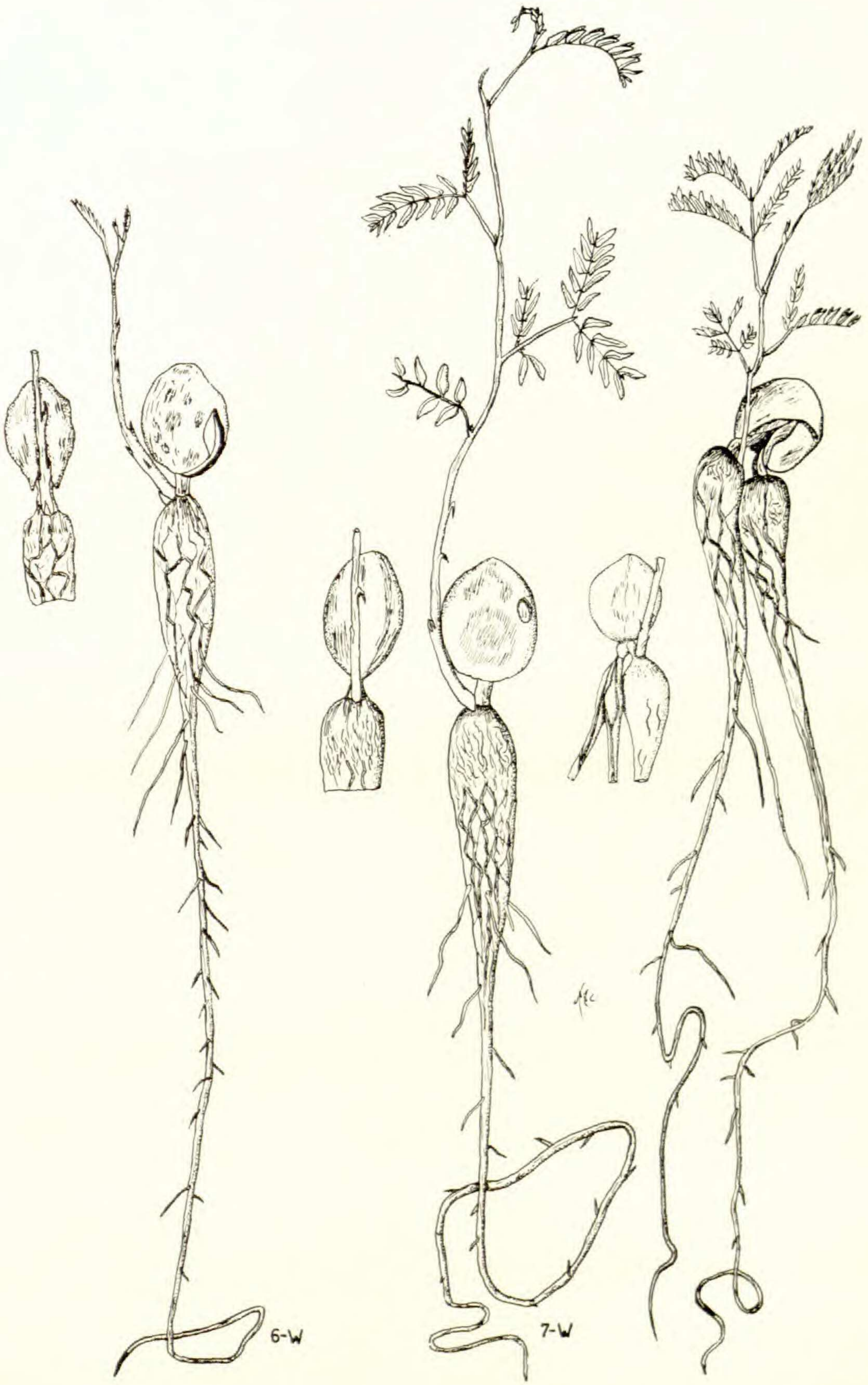


FIGURE 13, a and b. Different stages in the germination of the seeds and the development of the seedlings to illustrate secondary thickening of the "tap root" and lateral root development.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